

Electron Cyclotron Resonance Ion Sources with High Stability and Long Lifetime

Preston Barrows and Gabriel Becerra

Phoenix Nuclear Labs, Madison, Wisconsin, USA

Corresponding Author: Preston Barrows, e-mail address: preston.barrows@phoenixnuclearlabs.com

Phoenix Nuclear Labs (PNL) has developed high current microwave ion sources (MWS) for a number of scientific and industrial applications with an emphasis on injectors for high yield neutron generators. Solenoid electromagnets surrounding a microwave resonant cavity produce a magnetic field tuned to match the electron cyclotron resonance (ECR) of 2.45 GHz microwaves. Input microwave power efficiently produces ions which are extracted into a high current, low emittance beam with a set of electrostatic lenses.

The PNL neutron generator couples the extracted beam to a DC electrostatic accelerator that transports the deuterium beam into either a solid or gas target to produce neutrons through the deuterium-deuterium fusion reaction. Additionally, a wide range of other gasses have been used in these ion sources including hydrogen, nitrogen, oxygen, and argon.

Applications being served by the PNL technology include thermal and fast neutron radiography, medical isotope production, externally driven sub-critical assemblies, explosives detection, nuclear instrumentation testing and calibration, semiconductor processing, and high energy physics research. For these applications, long lifetime, stability, high beam current, excellent beam performance, and high reliability are of critical importance.

As PNL's MWS design does not depend on filaments, electrodes, or other consumable components, exceptional reliability and long lifetimes are achievable. Continuous uptime of >99% and thousands of hours of operation have been demonstrated on multiple systems. The total beam current extracted from the ECR ion source is typically 50-75 mA at 50 kV for deuterium with an average current density of 125 mA/cm². Extracted deuterium beam currents as high as 90 mA have been measured with current density of 225 mA/cm². In addition, the high gas efficiency of the ion source allows a relatively low input gas flow rate of 1-5 SCCM, which reduces vacuum pumping requirements for the rest of the system.

For PNL's gas target neutron generators, excellent performance beam is required. A deuterium ion beam exceeding 50 mA must be focused to a diameter of only a few mm at a location several meters downstream from the ion source in order to achieve the approximately 1 million-fold pressure differential between the target and accelerator regions. In order to meet the strict emittance requirements, a custom, direct inject extraction system has been developed at PNL.

An overview of the PNL ion source will be given and operational data will be reported.